CHAPTER 10. NATIONAL IMPACTS ANALYSIS

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10.1 INTRODUCTION

This chapter describes the method for estimating the national impacts of candidate standard levels (CSLs) for analyzed metal halide lamp fixtures (MHLF). Because fixtures are designed to operate metal halide (MH) ballasts and lamps, the U.S. Department of Energy (DOE) chose the most common MH lamp and ballast used with each fixture to develop representative metal halide lamp fixtures. MH lamps will not be regulated under the proposed amended energy conservation standards for fixtures; however, the characteristics of complete metal halide lamp fixtures (energy consumption, installed cost, etc.) must be considered for estimating national impacts of fixture CSLs.

In the national impacts analysis (NIA), DOE assessed the cumulative national energy savings (NES) and the cumulative national economic impacts of CSLs. DOE measured energy savings as the cumulative quadrillion British thermal units (Btu), or "quads," of energy a CSL is expected to save the nation. DOE measured economic impacts as the net present value (NPV) in dollars of total customer costs and savings expected to result from a CSL. The analysis period over which DOE calculated the NPV and NES is from 2015 to 2044.

DOE determined both the NPV and NES for each CSL and each representative product class it selected in the engineering analysis (preliminary technical support document (TSD) chapter 5). In this rulemaking, DOE considered up to four CSLs for each of the representative fixture equipment classes.

DOE performed all NIA calculations using a Microsoft Excel spreadsheet, available at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/metal_halide_lamp_fixtures.html.

The following sections describe in detail the methodology and inputs for the NIA. Several NIA inputs, including per-unit costs, per-unit energy consumption, and national shipments, are discussed in other analyses. In describing the inputs to the NIA, this chapter references those analyses and presents new information on installed stock. Section 10.2 discusses DOE's fixture shipment forecasts by CSL, the installed stock of fixtures, and the mix of efficiencies of that stock. Section 10.3 discusses DOE's calculation of national energy consumption in the base and standards cases, and the resulting difference in NES between these cases. Section 10.4 discusses the NPV calculation. Section 10.5 presents the NES and NPV results by representative equipment class.

10.2 BASE-CASE AND STANDARDS-CASE FORECASTED EFFICIENCY DISTRIBUTIONS AND FIXTURE STOCKS

The characteristics of DOE's shipment forecasts (such as equipment costs and operating costs) and projected fixture stocks (such as average efficiency and energy consumption) are key aspects of DOE's NES and NPV estimates. This section describes these key characteristics of stock and shipments as they relate to the NES and NPV.

The projected distribution of fixture efficiencies shipped and fixture efficiencies in stock are key factors in determining the NPV. Two inputs to the NPV are the per-unit total installed cost and per-unit annual operating cost. The per-unit total installed cost often varies with the efficiency of fixtures shipped. Therefore, when higher efficiency fixtures are shipped, higher installed costs are often incurred. Chapter 8 of the preliminary analysis TSD describes how per-unit total installed costs vary as a function of efficiency for each MH fixture.

Per-unit annual energy consumption is a key input to the NPV (as an input to the per-unit operating cost) and NES. The per-unit annual energy consumption is a function of metal halide lamp fixture characteristics in the installed stock. The total installed stock of metal halide lamp fixtures is used to determine total annual energy consumption, a key input into the NES and NPV calculations.

Also important to determining NES and NPV is the average efficiency of the MH fixture stock. The engineering analysis (preliminary TSD chapter 5) discusses the relationship between metal halide lamp fixture design, system input power, and fixture efficiency. The energy use characterization (preliminary TSD chapter 6) describes how the per-unit energy consumption varies as a function of system input power and market sector application for each metal halide lamp fixture design.

Sections 10.3.3 and 10.4.2 discuss inputs to calculation of the NES and NPV in further detail.

10.2.1 Base-Case and Standards-Case Efficiency Distributions

Because the end-user price of fixtures varies with efficiency level, the base-case and standards-case forecasted efficiency distributions of shipments affect the average total installed cost per unit. Generally, as the efficiency of a metal halide lamp fixture design increases, the total installed cost increases as well. In addition, the base-case and standards-case efficiency distributions affect the average fixture efficiency in the installed stock, an indication of annual energy consumption. For fixtures, DOE first presented the market share apportionments in the base case in preliminary TSD chapter 9. These market share apportionments characterize the shipments of fixtures for each analyzed equipment class. The forecasted efficiency distributions of shipments for fixtures depend directly on these apportionments and the total shipments of a particular fixture type in each year of the analysis period.

10.2.2 Installed Fixture Stock

The installed fixture stock in a given year is the total number of fixtures shipped that year and in prior years that are still operating. The NES model tracks the fixtures shipped each year, and fixtures are retired when they reach the end of their lifetime. From this information and the shipments forecasts presented in chapter 9, DOE established the installed fixture stock profile for all analyzed fixture equipment classes. Please see preliminary TSD chapter 9 for plots of the installed fixture stock profiles for each equipment class.

For most types of fixtures, installed stock increases over time. However, some fixture types experience a decline in stocks over the analysis period due to the encroachment of newer technologies such as induction (electrodeless fluorescent), high-intensity fluorescent, light-emitting diode (LED), and light-emitting plasma (electrodeless metal halide) fixtures.

10.3 NATIONAL ENERGY SAVINGS

10.3.2 National Energy Savings Definition

DOE calculated annual national energy savings as the difference in energy consumption by metal halide lamp fixtures between the base case (without new standards) and the standards case (with new standards). Positive values of NES correspond to net energy savings following standards implementation; *i.e.*, national annual energy consumption (AEC) with standards is less than AEC in the base case.

$$NES_t = (AEC_{t,base} - AEC_{t,std}) \times src\_conv_t \qquad \textbf{Eq. 10.1}$$

Where:

NES_t = national energy savings in year t,
AEC = annual national energy consumption each year (at the source) in quadrillion British thermal units (quads),
t = year in the forecast (*e.g.*, 2015 to 2044),
$base$ = base case,
std = standards case, and
src_conv_t = time-dependent conversion factor to convert from site energy (kWh) to source energy (quads, Btu/kWh).

Cumulative energy savings are the sum over a defined time period from the implementation of a standard forward (from 2015 to 2044) of the annual national energy savings.

$$NES_{cum} = \sum_t NES_t \qquad \textbf{Eq. 10.2}$$

Where:

NES_{cum} = cumulative national energy savings.

DOE calculated the AEC (in any year) by multiplying the number or stock of fixtures by the product of the annual unit energy consumption and the site-to-source conversion factor, shown by the following equation:

$$AEC = \sum_{bd} STOCK_{bd} \times UEC_{bd} \qquad \textbf{Eq. 10.3}$$

Where:

bd = fixture ID number,
$STOCK_{bd}$ = stock of fixtures for a given design surviving in the year for which DOE calculated AEC, and
UEC_{bd} = unit energy consumption (kWh per year).

10.3.3 National Energy Savings Inputs

Table 10.3.1 lists the inputs for the determination of NES.

Table 10.3.1 National Energy Saving Inputs

Input
Unit Energy Consumption, UEC
Fixture Stock by Design ($STOCK_{bd}$)
Site-to-Source Conversion Factor (*src_conv*)

10.3.3.1 Unit Energy Consumption (UEC)

DOE presents the per-unit UEC for each metal halide lamp fixture design in the energy use characterization (preliminary TSD chapter 6). For the NES and NPV calculations, DOE used an average number of annual operating hours for each sector in calculating the UEC of each MHLF design.

10.3.3.2 Fixture Stock

The fixture stock in a given year is the sum of the shipments in that year, and the total number of fixtures shipped in prior years that survive. The NES spreadsheet model keeps track of the fixtures shipped each year. DOE discusses forecasted shipments for the base case and all standards cases in chapter 9. To generate the shipments that eventually comprise the fixture stock, the shipments analysis incorporates one set of base-case scenarios and one set of standards-case scenarios that can affect shipments. The base-case scenarios determine the total volume of fixture shipments and installed stock. The standards-case scenarios are composed of the roll-up and shift scenarios. These scenarios dictate the inputs to the market-share apportionments, and therefore affect the breakdown of the installed stock by fixture design from 2015 to 2044. The shift scenario generally results in higher energy savings than the roll-up scenario.

10.3.3.3 Site-to-Source Conversion Factors

The site-to-source conversion factor is the multiplier DOE used for converting site-energy consumption into primary or source energy consumption. For electricity, the conversion factors can vary over time due to projected changes in generation sources (*i.e.*, the power plant types projected to provide electricity to the country). For the preliminary analysis, DOE used a site-to-source conversion factor of 10,329, derived from the 2010 version of the Energy Information Administration's (EIA's) *Annual Energy Outlook* (*AEO2010*), and will update to the latest available version of the *AEO* during the next phase of the analysis.[1] DOE will also incorporate time-dependent changes in the site-to-source conversion factor in the next phase of the analysis.

10.3.3.4 Interactions with Heating, Ventilation, and Air-Conditioning (HVAC) Systems

Interactions with HVAC systems in the commercial and industrial sectors are represented by an HVAC factor, as given in Eq. 10.3. The HVAC factor reflects the extent to which the energy savings from more efficient equipment are offset by increased demands placed on heating and cooling equipment in the presence of more efficient equipment. Typically this takes the form of increased efficiency being achieved through less energy wasted as heat, increasing the burden on HVAC equipment in winter months.

In a previous rulemaking (the 2010 fluorescent ballast rule), DOE found that the HVAC factor is highly dependent on the composition of building stock[2]. Due to the great uncertainty in building stock, DOE used an HVAC factor of 1 for calculating energy savings in the preliminary analysis.

10.3.3.5 Rebound Effect

In its analysis, DOE considered the rebound effect that occurs after installation of energy-efficient lighting equipment. Under economic theory, "rebound effect" refers to the tendency of a consumer to respond to the cost savings associated with more efficient equipment in a manner that actually leads to marginally greater product usage, thereby diminishing some portion of anticipated benefits related to improved efficiency. DOE examined a summary of the literature regarding the rebound effect in relation to lighting equipment.[3] Based on four studies, the summary estimated that for a 100-percent increase in energy efficiency, "take-back" or rebound values for residential lighting are between 5 and 12 percent of energy consumption savings. The summary estimated zero to 2 percent rebound values for commercial and industrial lighting. For the commercial and industrial equipment considered in this rulemaking, DOE believes that equipment use is driven by the application needs, and that affected consumers will not alter their usage patterns in response to incremental efficiency gains. Therefore, in this preliminary analysis, DOE assumed a zero percent rebound effect in all three sectors analyzed.

10.4 NET PRESENT VALUE

10.4.1 Net Present Value Definition

The NPV is the value in the present of a time series of costs and savings. The NPV is calculated as follows:

$$NPV = PVS - PVC \qquad \textbf{Eq. 10.4}$$

Where:

PVS = present value of operating cost savings, and
PVC = present value of increased total installed costs.

The PVS and PVC are determined according to the following expressions:

$$PVS = \sum OCS_t \times DF_t \qquad \textbf{Eq. 10.5}$$

$$PVC = \sum TIC_t \times DF_t \qquad \textbf{Eq. 10.6}$$

Where:

OCS_t = total annual operating cost savings in year t,
TIC_t = total annual installed cost increases in year t,
DF_t = discount factor associated with year t, and
t = year (*PVS* and *PVC* are summed over 2015–2044).

DOE determined the contributions to PVC and PVS for each year from 2015 to 2044, and discounted these costs to 2011. DOE calculated savings as the difference between a standards case (*i.e.*, with amended standards) and a base case (*i.e.*, without amended standards). DOE discounted savings using the discount rate and the number of years between the "present" (*i.e.*, year to which the sum is being discounted) and the year in which the costs and savings occur. DOE calculated the net present value as the sum over time of the discounted net savings (which is equivalent to the approach shown in Equations 10.4 through 10.6).

10.4.2 Net Present Value Inputs

Table 10.4.1 summarizes the inputs to the NPV calculation.

Table 10.4.1 Net Present Value Inputs

Input
Total Annual Installed Cost Increases (*TICt*)
Total Annual Operating Cost Savings (*OCSt*)
Discount Factor

10.4.2.1 Total Annual Installed Cost Increases

DOE calculated the increase in total annual installed costs as the difference between the total annual installed costs in the standards case minus those in the base case. For each case, the total annual installed costs equal the product of the shipments and per unit installed cost (summed over each fixture design). DOE used an average lifetime of each fixture type for each equipment class.

10.4.2.2 Total Annual Operating Cost Savings

As the life-cycle cost (LCC) and payback period (PBP) analysis (preliminary TSD chapter 8) describes, DOE calculated total annual operating costs based on national average electricity prices. DOE calculated total annual operating cost savings as the difference between total annual operating costs in the base case minus those in the standards case. (The only component of annual operating cost for metal halide lamp fixtures that is different between the base case and the standards case is the cost of electricity consumption.)

$$OCS_t = \sum_{bd} STOCK_{bd} \times UEC_{bd} \times electricity\ price \qquad \textbf{Eq. 10.7}$$

Where:

OCS_t = total annual operating cost savings in year t,
$STOCK_{bd}$ = total stock of fixture type bd,
UEC_{bd} = unit energy consumption of fixture type bd,
electricity price = electricity price associated with fixture type bd,
t = year, and
bd = fixture ID number.

DOE used an average number of annual operating hours for each sector and fixture type in calculating the UEC of each MHLF. DOE used *AEO2010* to establish all electricity prices.[4] Chapter 8 provides the electricity price forecasts DOE used to calculate the NPV.

10.4.2.3 Discount Factor

DOE multiplied monetary values in future years by the discount factor (DF) to calculate the present value. The following equation describes how to calculate the discount factor:

$$DF = 1/(1+r)^{(t-t_p)} \qquad \textbf{Eq. 10.8}$$

Where:

r = discount rate,
t = year of the monetary value, and
t_p = year in which the present value is being determined.

DOE estimated national impacts with both a 3-percent and a 7-percent real discount rate as the average real rate of return on private investment in the U.S. economy. These discount rates were used in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on the development of regulatory analysis (OMB Circular A-4, September 17, 2003), and section E, "Identifying and Measuring Benefits and Costs," therein.[5] DOE defined 2011 as the year to which future expenses are discounted.

10.5 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE RESULTS

The NES spreadsheet model provides estimates of the NES and NPV due to various CSLs. The inputs to the NES spreadsheet are discussed in sections 10.3.3 and 10.4.2. DOE generated the NES and NPV results using Microsoft Excel spreadsheets, accessible at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/metal_halide_lamp_fixtures.html.

10.5.1 National Energy Savings and Net Present Value Input Summary

Table 10.5.1 summarizes the inputs to the NES spreadsheet model. A brief description of the data is given for each input.

Table 10.5.1 National Energy Saving and Net Present Value Inputs

Input Data	Data Description
Shipments	Annual shipments from the fixture shipments model. Historical shipments are based on U.S. Census Bureau Current Industrial Reports data (preliminary TSD chapter 9).
Stock of Fixtures	Established based on historical and projected fixture shipments, the service life of fixtures, and growth rates.
Effective Date of Standard	2015.
Analysis Period	2015 to 2044.
Unit Energy Consumption (kWh/yr)	Established in the energy-use characterization (preliminary TSD chapter 6) by metal halide lamp fixture and sector.
Total Installed Cost	Established in the markups analysis (preliminary TSD chapter 7) and LCC analysis (preliminary TSD chapter 8) by MHLF.
Electricity Price Forecast	EIA forecasts (to 2035) from the *AEO2010* and extrapolation for beyond 2035 (preliminary TSD chapter 8).
Electricity Site-to-Source Conversion	Assumed to be constant across time: 1 site kWh = 10,239 source Btu.
HVAC Interaction Savings	1.
Rebound Effect	0%.
Discount Rate	7 and 3 percent real.
Present Year	Future costs and savings are discounted to 2011.

10.5.2 National Energy Savings Results

The following section provides NES results for each CSL that DOE considered for fixtures. Results are cumulative to 2044 and are shown as primary energy savings measured in quads.

Table 10.5.2 shows the NES results under roll-up and shift scenarios, which reflect the lower and upper bounds, respectively. Since the shift scenario models more consumers moving to higher-efficiency metal halide lamp fixtures than in the roll-up scenario, the shift scenario results in higher energy savings.

Table 10.5.2 presents total national energy savings for each CSL by fixture type and in total. However, it is important to note that the numbers presented in these tables are calculated assuming that all fixture types face the same CSLs.

Table 10.5.2 Cumulative National Energy Savings for Fixtures under the Roll-Up and Shift Scenarios (2015–2044)

Candidate Standard Level	Equipment Class	National Energy Savings (quads)					
		Roll-Up Scenario			Shift Scenario		
		7% Discount Rate	3% Discount Rate	0% Discount Rate	7% Discount Rate	3% Discount Rate	0% Discount Rate
1	70W Fixtures	0.01	0.03	0.05	0.01	0.03	0.06
	250W Fixtures	0.05	0.11	0.21	0.05	0.11	0.21
	400W Fixtures	0.07	0.14	0.27	0.07	0.14	0.27
	1000W Fixtures	0.03	0.06	0.12	0.03	0.06	0.12
	Total	0.16	0.34	0.65	0.16	0.35	0.67
2	70W Fixtures	0.05	0.11	0.21	0.05	0.11	0.21
	250W Fixtures	0.07	0.15	0.29	0.07	0.15	0.29
	400W Fixtures	0.12	0.26	0.49	0.12	0.26	0.49
	1000W Fixtures	0.06	0.12	0.24	0.06	0.12	0.24
	Total	0.30	0.65	1.23	0.30	0.65	1.24
3	70W Fixtures	0.06	0.12	0.22	0.06	0.12	0.22
	250W Fixtures	0.11	0.23	0.43	0.11	0.23	0.43
	400W Fixtures	0.15	0.33	0.62	0.15	0.33	0.62
	1000W Fixtures	0.06	0.12	0.24	0.06	0.12	0.24
	Total	0.37	0.80	1.51	0.37	0.80	1.52
4	70W Fixtures	0.06	0.12	0.22	0.06	0.12	0.22
	250W Fixtures	0.11	0.24	0.46	0.11	0.24	0.46
	400W Fixtures	0.19	0.40	0.77	0.19	0.40	0.77
	1000W Fixtures	0.06	0.12	0.24	0.06	0.12	0.24
	Total	0.42	0.89	1.69	0.42	0.89	1.69

Note: Totals may not match the sum of equipment class savings due to rounding.

10.5.3 Net Present Value Analysis

The NPV calculation attempts to calculate the total monetary costs and benefits of the standard for all consumers of fixtures. This calculation relies primarily on two inputs: the NES calculations described in the previous section, which are translated into a decrease (or in some cases increase) in operating costs; and the increase (or in some cases decrease) in installed costs.

In most cases the operating cost savings, installed costs increases, and NPV all trend toward zero over time, reflecting the impacts of discounting.

NPV results are cumulative and shown as the discounted value of these savings in dollar terms. DOE used national averages for key inputs such as electricity pricing and sector-specific point values for operating hours in calculating operating cost savings and installed cost increases. Thus, the NPV results are discrete point values rather than a distribution of values as in the LCC and PBP analyses.

The present value of increased total installed costs is the total installed cost increase (*i.e.*, the difference between the standards case and base case in given year), discounted to the present, and summed over the time period in which DOE evaluated the impact of standards (*i.e.*, from the effective date of standards, 2015 to 2044).

Savings are decreases in operating costs associated with higher efficiency fixtures purchased in the standards case compared to the base case. DOE calculated total annual operating cost savings as the difference between total annual operating costs in the base case minus those in the standards case. Eq. 10.7 gives the total annual operating costs in each case.

In general, the NPV results at each CSL largely reflect the LCC savings at the corresponding efficiency levels. As discussed in the LCC and PBP analyses (preliminary TSD chapter 8), for most fixture purchasing events and most baseline fixture designs, increasing efficiency levels generally results in increased LCC savings; however, at certain efficiency levels (which differ by equipment class), electronic ballasts are used instead of magnetic ballasts. Electronic ballasts are more expensive and have a shorter lifetime than magnetic ballasts, and the associated maintenance costs with replacing electronic ballasts more frequently far outweigh the monetary benefits of energy savings. Therefore, the efficiency levels which require electronic ballasts do not generate positive LCC savings.

10.5.4 Net Present Value Results

Table 10.5.3 shows the NPV results in tabular format for both the roll-up and shift scenarios, which represent the lower and upper energy savings, respectively. Within each of these scenarios, results are also shown for 7- and 3-percent discount rates. Increases in energy savings do not necessarily correspond to increases in NPV savings.

Table 10.5.3 Cumulative NPV Results for Metal Halide Lamp Fixtures (2015-2044)

Candidate Standard Level	Equipment Class	Net Present Value *billion 2010$*			
		Shift Scenario		Roll-Up Scenario	
		7% Discount Rate	3% Discount Rate	7% Discount Rate	3% Discount Rate
1	70W Fixtures	0.104	0.223	0.124	0.265
	250W Fixtures	0.258	0.615	0.294	0.692
	400W Fixtures	0.167	0.477	0.208	0.562
	1000W Fixtures	0.118	0.304	0.111	0.288
	Total	**0.647**	**1.619**	**0.736**	**1.806**
2	70W Fixtures	-0.385	-0.773	-0.380	-0.763
	250W Fixtures	0.180	0.506	0.248	0.652
	400W Fixtures	0.350	0.952	0.443	1.149
	1000W Fixtures	0.313	0.758	0.313	0.758
	Total	**0.457**	**1.442**	**0.624**	**1.796**
3	70W Fixtures	-0.472	-0.932	-0.472	-0.932
	250W Fixtures	-2.878	-5.856	-2.884	-5.867
	400W Fixtures	-3.365	-6.740	-3.351	-6.714
	1000W Fixtures	0.313	0.758	0.313	0.758
	Total	**-6.403**	**-12.770**	**-6.395**	**-12.755**
4	70W Fixtures	-0.472	-0.932	-0.472	-0.932
	250W Fixtures	-2.647	-5.386	-2.647	-5.386
	400W Fixtures	-3.944	-7.810	-3.944	-7.810
	1000W Fixtures	0.313	0.758	0.313	0.758
	Total	**-6.750**	**-13.370**	**-6.750**	**-13.370**

Note: Totals may not match the sum of equipment class savings due to rounding.

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